

or more are selected to use from among water and organic solvents that can dissolve or disperse the raw material containing the constituent ceramic elements. As for the organic solvents, mainly acetic acid, dimethyl formamide, methoxyethanol, alcohols, glycols etc. are used.

As for the combustion aid, citric acid is used, which is an organic compound that can give rise to combustion reaction. In the conventional method, the citric acid has been used not as a combustion aid but a complexing agent in order to give reaction uniformity and has been used in process such as Pechini process, where speed-controlled combustion reaction can be induced using citric acid's flammability and complex formation effect.

A mixture is made by adding citric acid into a solution or a dispersed mixture where constituent ceramic elements are dissolved or dispersed. The quantity of the citric acid added shall not be less than the necessary amount to give rise to oxidative-reductive combustion reaction with the anion of the constituent ceramic element. Reaction speed can be controlled by the quantity of citric acid added.

The mixture made by the addition of the citric acid is thermally treated at 100-500°C. Though the crystallinity of the ceramic phase increases as the temperature for the thermal treatment, the citric acid combustion reaction may start enough if only temperature for the thermal treatment is over 100°C. And though reaction can arise even if the temperature for the thermal treatment is above 500°C, thermally treating above that temperature is meaningless when comparing with the conventional method.

More preferably it shall be thermally treated at 150-300°C which is a temperature range can secure suitably the crystallinity of the ceramic phase although it is considerably low temperature range for a thermal treatment.

5 If the mixture is thermally treated to vaporize the solvent or the dispersant, the added citric acid acts as a reductive combustion aid and is removed giving rise to nonexplosive oxidative-reductive combustion reaction with the anion of constituent ceramic element, when the ceramic oxide is formed without scattering out by virtue of reaction heat generated at this time.

10 And in the reaction, components other than the constituent ceramic element are removed during sufficient time of combustion reaction so that the ultrafine ceramic oxide powder of pure type without impurity is obtained.

15 The particle size of the ultrafine ceramic oxide powder obtained by the method is below 1 μm , and is specifically 0.01-0.1 μm so extremely fine with uniform powder particle diameter distribution. The primary particles of which powder exist as independent bodies or as a soft aggregate type, and are in completely burnt ceramic phase so that the weight does not decrease even by additional thermal treatment.

20 And because the powder has excellent surface reactivity so that molding is feasible even only with a thermal treatment at low temperature, the degree of freedom for a vibration plate is high and diverse methods of printing and coating can be applied.

25 But it may additionally comprises a step of conducting additional thermal treatment of the obtained ultrafine ceramic

oxide powder at 700-900°C to increase the crystallinity of the powder produced.

A method for forming a piezoelectric/electrostrictive film element at low temperature by electrophoretic deposition process using ultrafine ceramic oxide powder will be explained. Figure 3 shows a method for forming a piezoelectric/electrostrictive film element at low temperature by electrophoretic deposition process.

As for the ceramic oxide powder, the ultrafine ceramic oxide powder obtained by the method is used because it is effective to use fine powder to secure system feasible of forming at low temperature considering the powder reactivity itself.

The ultrafine ceramic oxide powder produced has small ceramic particle size with uniform size distribution and no voids so that it can get ideal stacking result with maximum bonding strength between particles.

Whence it is preferable to use PZT, PMN or their solid solution (PZT-PMN) complex oxides as for the ultrafine ceramic oxide powder.

And the ultrafine ceramic oxide powder may additionally comprises one or more components among nickel (Ni), lanthanum (La), barium (Ba), zinc (Zn), lithium (Li), cobalt (Co), cadmium (Cd), cerium (Ce), chromium (Cr), antimony (Sb), iron (Fe), yttrium (Y), tantalum (Ta), tungsten (W), strontium (Sr), calcium (Ca), bismuth (Bi), tin (Sn) and manganese (Mn).

Because interparticle vacancy exists no matter how closely it approaches ideal stacking state, in order to improve density